Toxicity approaches to assessing mining impacts and minewaste treatment effectiveness.

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Abstract

The U.S. EPA Office of Research and Development's National Exposure Research Laboratory and National Risk Management Research Laboratory have been evaluating the impacts of mining sites on receiving streams and the effectiveness of waste treatment technologies in removing toxicity for the past six years. The effectiveness of site assessments and minewaste treatment technologies in reducing toxicity was assessed using toxicity tests on the Summitville mine site, Clear Creek and North Fork of Clear Creek, Burleigh Tunnel and Big Five Tunnel in Colorado and Calliope Mine, Crystal Mine, Lilly/Orphan Boy Mine, Peerless Mine and Sure Thing Mine in Montana. Water samples were collected from these sites or mining sites and shipped to the U.S. EPA Aquatic Research Facility in Cincinnati, Ohio. A series of acute aquatic toxicity tests with *Pimephales promelas*, the fathead minnow and *Ceriodaphnia dubia*, a freshwater invertebrate were conducted on these samples. In addition to these tests, a 7-day growth test using rainbow trout, *Oncorhynchus mykiss*, was conducted on Summitville minewaste samples. The purpose of these tests was to establish the level of toxicity for the discharge from the different mines sites and to evaluate the effectiveness of different treatment processes used at these sites. The results from the tests on the effluents from treatment technologies used at the Sure Thing and Lily Orphan Boy mine sites indicate that there is a significant reduction in toxicity. For the Sure Thing Mine treated effluent, *C. dubia* survival LC50 value was increased by 670 fold and the No Observable Acute Effect Level (NOAEL) by 640 fold. The *P. promelas* LC50 value was increased by 24 fold and the NOAEL value by 20 fold. For the Lily Orphan Boy treated effluent the *C. dubia* LC50 value increased by 160 fold and the NOAEL by 320 fold. The *P. promelas* LC50 value increased by 21 fold and the NOAEL by 40 fold. For the Summitville Mine treatment System, treated mine discharge samples displayed reduced toxicity of approximately 7-8 fold for *C. dubia*, 10 fold for rainbow trout, and about 5 fold for the fathead minnow as compared to untreated mine waste. However, in order to remove all the acute toxicity from the mine discharge, the concentration of metals from both treatments have to be reduced by 1000 fold for *C. dubia* survival, or 100 or 50 fold for rainbow trout, and fathead minnow survival respectively.

Introduction

The National Risk Management Research Laboratory (NRMRL) and the National Exposure Research Laboratories have been collaborating on evaluations of the effectiveness of mine treatment technologies and assessing the instream impacts of mines for the past 8 years. The objective of this collaboration was to use toxicity and bioassessment methods for assessing the success of pilot mine waste treatment technologies on removal of metals from mine dischargers or seeps. We will cover what the results have been to date in assessing a pilot treatment project at the Summittville Mine in Colorado, an artifically contructed wetland piloted at the Burleigh Tunnel discharge in Colorado, and several different treatment strategies employed at the following mines in Montana, Calliope Mine, Crystal Mine, Lilly/Orphan Boy Mine, Peerless Mine and Sure Thing Mine. We also will show results of three toxicity assessments of three streams in Colorado, Alamosa River and tributaries, Clear Creek and North Fork of Clear Creek.

Test Methods

Standard Operating Procedures for *Ceriodaphnia dubia* acute toxicity tests

TEST CRITERIA	SPECIFICATIONS
Test Type	Static-renewal
Test Duration	48 hr
Temperature	20°C ± 1°C
Photoperiod	16 hr light/8 hr dark
Test Chamber Size	30 ml (plastic cups)
Test Solution Volume	20 ml
Renewal of Test solution	Daily
Age of Test Organisms	Less than 24-hr-old
Number of Organisms/ per test chamber	5
Number of Replicate Chambers/Conc.	4
Number of Organisms/ Concentration	20
Feeding	none, fed while holding prior to test setup
Dilution Water	Moderately Hard Reconstituted Water
Endpoint	Mortality, LC50
Test Acceptability	90% survival in the controls

Standard Operating Procedures for *Pimephales promelas* acute toxicity tests

TEST CRITERIA	SPECIFICATIONS
Test Type	Static-renewal
Test Duration	48 hr
Temperature	20°C ± 1°C
Photoperiod	16 hr light/8 hr dark
Test Chamber Size	175 ml (plastic cups)
Test Solution Volume	150 ml
Renewal of Test- solution	Daily
Age of Test Organisms	3 to 7 days ± 24 hr age range
Number of Organisms/ per test chamber	10
Number of Replicate- Chambers/Conc.	2
Number of Organisms/ Concentration	20
Feeding	Feed newly hatched brine shrimp prior to testing. Do not feed during the test.
Dilution Water	Moderately Hard Reconstituted Water
Endpoint	Mortality, LC50
Test Acceptability	≥90% survival in the controls

Standard Operating Procedures for *Pimephales promelas* embryo-larval sediment toxicity test.

TEST CRITERIA	SPECIFICATIONS
Test Type	Static-renewal
Test Duration	7 days (8 24H time periods)
Temperature	25 °C ± 1 °C
Photoperiod	16 hr light/8 hr dark
Test Chamber Size	100 ml
Sediment Volume	40 ml
Overlying Water Volume	60 ml
Renewal of Test solution	daily
Age of Test Organisms	24-48 hour old embryo
Number of Organisms/ per test chamber	10
Number of Replicate Chambers/Conc.	4
Number of Organisms/ Concentration	40
Feeding	none
Dilution Water	Reformulated Moderately Hard Reconstituted Water
Control Sediment	grade 40 silica sand
Endpoints	Mortality, difference fromcontrol Hatch ability and abnormal embryo (terata)
Test Acceptability	> 80% survival in the controls

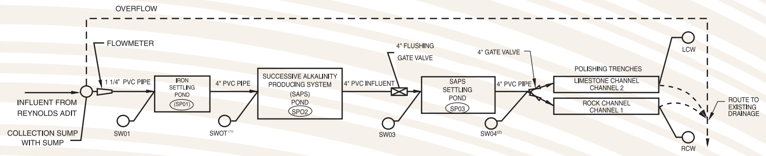
Standard Operating Procedures for *Oncorhynchus mykiss* Survival and Growth Toxicity Tests

TEST PARAMETER	CONDITION
Test Type	static-renewal
Test Duration	7 days
Temperature	25 °C (±1 °C)
Photoperiod	16 h light: 8 h dark
Test Chamber Size	500 ml
Test Solution Volume	400 ml
Renewal of Test Solution	daily
Age of Test Organisms	15 to 20 days old, 1 to 5 days post swimup
No. Organisms/Test Chamber	5
No. Replicate Test Chambers	4
No. Organisms/concentration	20
Feeding Regime	1.5 ml conc. Brine shrimp 2X/day
Test Solution Aeration	None
Dilution Water	Moderately Hard Water
Endpoint	Survival and Mean Dry Weight
Test Acceptability	90% or greater control survival control growth 1.5X initial weight

Results

Summittville

Summittville Colorado is located in Southwestern Colorado and impacts the Alamosa River which is a tributary to the Rio Grande River. The U.S. Environmental Protection Agency has many programs for evaluating various methods to treat contaminated waste discharges. As part of a Superfund Innovative Technology Evaluation (SITE) Program, the USEPA evaluated a remediation technology at the Summitville Mine Superfund Site in southern Colorado. USEPA has instituted a program to develop a treatment system that will reduce the level of contamination, and therefore toxicity, of the wastewater discharged from this site. The technology evaluated was a successive alkalinity producing system (SAPS) for removing high concentrations of metals (aluminum, copper, iron, manganese, and zinc).



SAPS TREATMENT SYSTEM PROCESS FLOW SCHEMATIC

Comparison of Survival 11/00 results for Ceriodaphnia dubia**, Fathead Minnow (**Pimephales promelas**) and Rainbow Trout (**Oncorhynchus mykiss**) using samples from Summitville Mine drainage and pilot treatment effluents.**

Sample	Cerio 48-hr LC50	FH 48-hr LC50	Trout 7-day LC50	Trout NOEC
SW 01	0.01 %	0.29	0.25%	0.1%
SW 04	0.08 %	2.18	1.57%	1%
RCWT	0.07 %	2.12	1.67%	1%

(SW 01) = Mine Drainage
(SW 04 and RCWT) = discharge samples from two different treatment technologies

Conclusion

Based on these results the order of sensitivity to the Summitteville drainage is as follows: *Ceriodaphnia* is more sensitive than rainbow trout, than the fathead minnow. Both treatment technologies reduced toxicity by 7-8 fold for *Ceriodaphnia*, @ 10 fold for rainbow trout, and about 5 fold for the fathead minnow. However, a substantial amount of toxicity remains. An additional 100 fold reduction in metals needs to be accomplished to have no acute toxicity to rainbow trout, a 1000 fold reduction in both treatments to have a no acute effect on *Ceriodaphnia* and a 50 fold reduction for no acute effects on fathead minnows.

Burleigh Tunnel

The Burleigh Tunnel is located in Silver Plume, Clear Creek County, Colorado. Silver Plume is approximately 80 miles from Denver, Colorado.. The Burleigh Tunnel geochemical metal loading to Clear Creek is more significant in low flow months prior to and after spring run-off. Data suggests that zinc levels in Clear Creek are elevated during the low-flow months and lower during the spring run-off due to dilution.

In 1994 two Constructed Wetland System (CWS) treatment cells were located adjacent to the Burleigh adit. One cell was an upflow system, while the other was a downflow system. Each cell covers 0.05 acres. The flow to the cells was regulated by a pair of v-notch weirs, one for the influent and one for the effluent. The estimated total volume of substrate in the upflow cell was 212 cubic yards and 223 cubic yards in the downflow cell. The base of each cell is made up of a gravel subgrade, a 16 oz. geofabric, a sand layer, a clay liner, followed by a high density polyethylene liner. The base is separated from the influent piping by a GEONET. The substrate is composed of a mixture of 96% processed manure and 5% hay. The compost is produced from cattle manure and unidentified paper products.

Results from toxicity tests with Ceriodaphnia dubia **in samples from the Burleigh Tunnel**

WIO = Mine Drainage
WEU = Wetland Effluent from Up Flow Cell
WED = Wetland Effluent from Down Flow Cell

Sample	LC50 % Sample	Limits
WIO 2/95	1.01	0.59 - 1.71
WIO 6/95	0.105	No Limits
WIO 12/96	0.09	0.05-0.17
WIO 6/97	0.43%	0.32-0.57
WIO 10/97	0.15%	0.09-0.26
WEU 2/95	8.41	6.25 - 11.33
WEU 6/95	0.51	0.41 - 0.64
WEU 12/96	0.22	0.18-0.27
WEU 6/97	0.41	0.34-0.48
WEU 10/97	0.13%	0.11-0.16
WED 2/95	>100%	
WED 6/95	2.56%	No Limits
WED 10/97	0.19%	0.14-0.26

Results from toxicity tests with Pimephales promelas **in samples from the Burleigh Tunnel site**

Sample	LC50 % Sample	Limits
WIO 2/95	1.55	1.23 -1.93
WIO 6/95	1.01	0.77 - 1.32
WIO 12/96	0.69%	0.56-0.86
WIO 6/97	1.02%	0.91-1.15
WIO 10/97	1.35%	1.13-1.62
WEU 2/95	100%	No Limits
WEU 6/95	2.27%	1.87-2.77
WEU 12/96	1.59%	1.19-2.14
WEU 6/97	23.7%	17.0-32.9
WEU 10/97	14.23%	11.63-17.43
WED 2/95	>100%	
WED 6/95	2.56%	No Limits
WED 10/97	10.58%	8.22-13.61

Burleigh Tunnel - Continued

Results of the O. mykiss **survival and growth toxicity tests using Burleigh Tunnel sample 6/97**

Sample	NOEC	LOEC	MSD	LC50	NEOC	LOEC	MSD	IC25	IC50
WIO (%)	0.156	0.313	0.011	0.245	<.156	>.156	18.4	0.185	0.254
Zinc Car (µg/L)	125	250	0.005	238.6	>125	>125	6.8	178.5	269.0

Conclusions

Early results (2/95) indicated that the Wetland was very successful in reducing toxicity. However, toxicity in the wetland effluents became similar to the mine waste discharge because of pluging of the wetland substrate and hydraulic channeling through the wetland.

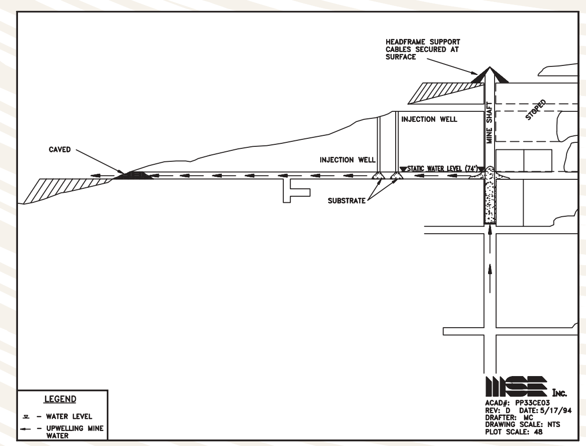
7-day Trout tests were similar to 48-hr acute *Ceriodaphnia* and fathead minnow results.

U.S. EPA Minewaste Treatment Technology Program

Lilly/Orphan Boy Mine

The Lilly/Orphan Boy Mine is located near Elliston, Montana. Aqueous waste is contained in a shaft that is treated by using the mine as an in-situ reactor. The shaft of the mine runs to a depth of 250 feet and is flooded to the 74-foot level, the typical level which was historically discharged from the portal. Organic substrate composed of cow manure, woodchips, and alfalfa was supported by two platforms and lowered into the shaft to promote growth of the organisms. Injection wells were drilled into the main tunnel so the substrate could be placed into this space to monitor removal efficiencies at different sampling ports

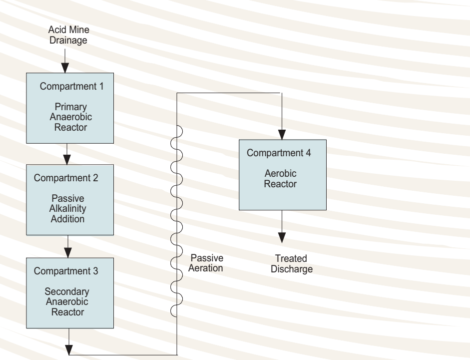
Biological sulfate reduction is accomplished by heterotrophic, anaerobic SRBs. The sulfate reducing bacteria (SRB) chosen for this demonstration require a reducing environment and cannot tolerate aerobic conditions for extended periods. These bacteria require a simple organic nutrient; a mixture of cow manure, woodchips, and alfalfa. The process is accomplished via three mechanisms. First, hydrogen sulfide is produced from sulfate dissolved in AMD and organic substrate through SRB metabolic action. Next, the hydrogen sulfide reacts with dissolved metal ions in AMD to produce insoluble metal sulfides. Finally, the bacterial metabolism of the organic substrate produces bicarbonate which increases the pH of the solution thus limiting further metal dissolution.



Cross-section of the Lilly/Orphan Boy Mine and the technology installation.

Sure Thing Mine

The Sure Thing mine is located in Southwest Montana. At this site the treatment technology employed uses a series of biological processes for the complete mitigation of AMD by concentrating and immobilizing metals within bioreactors and raising the pH of the water. The field system is composed of a primary anaerobic reactor, a passive alkalinity limestone reactor, a secondary anaerobic reactor, a passive aeration system which includes corrugated pipes, and an aerobic reactor..



Mine Technology Program Results 2001

Cresent Mine SRB influent and effluent,
SureThing Mine (ST) influent and effluent
Lily Orphan Boy (LOB) PT3 and PT6.

Results from toxicity tests with Ceriodaphnia dubia.

Sample	Conc. (%)	Survival	LC50 (%)	Limits	NOAEL (%)	MSD
SRB-INF	cnt	20/20	0.18	0.14-	0.078	15.01
SRB-EFF	cnt	19/20	49.79	16.66-	25	14.78
ST-INF	cnt	18/20	0.15	0.11-	0.156	36.06
ST-REC-EFF	cnt	20/20	>100	N/A	>100	N/A
LOB PT 3	cnt	20/20	0.63	0.45-0.89	0.156	18.65
LOB PT 6	cnt	18/20	100	N/A	50	39.86
Zinc Ref Tox	cnt	20/20	154.12 µg/l	123.68-192.05	62.5 µg/l	17.77

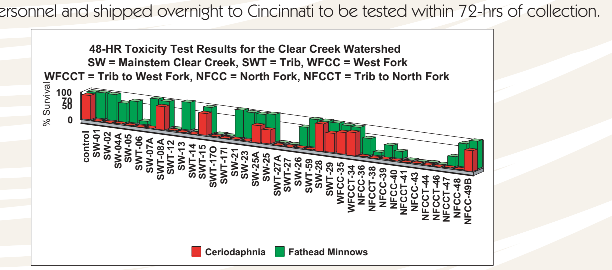
Results from toxicity tests with Pimephales promelas.

Sample	Conc. (%)	Survival	LC50 (%)	Limits	NOAEL (%)	MSD
SRB-INF	cnt	20/20	0.56	0.43-0.73	0.3125	17.09
SRB-EFF	cnt	20/20	>100	N/A	>100	N/A
ST-INF	cnt	19/20	4.12	3.25-5.23	2.5	24.31
ST-REC EFF	cnt	20/20	>100	N/A	50	17.12
LOB PT 3	cnt	20/20	3.80	2.84-5.09	1.25	11.57
LOB PT 6	cnt	20/20	79.37	93.7-67.22	50	18.18
Zinc Ref Tox	cnt	20/20	745.30	553.88 -1003	250µg/l	26.25

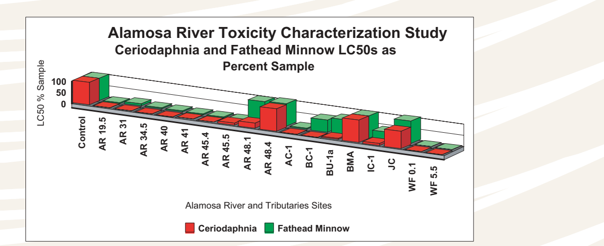
The results from the tests indicate that the treatment systems being used to remediate the waste from these three mine sites are working. The first indication was in the arrival chemistry values for each sample, where the pH value and alkalinity for the treated samples from each mine were considerably higher than that of the mine discharge samples. The results from the toxicity tests with **C. dubia** and **P. promelas** show that the survival of the animals is improved in the treated samples when compared to the discharge samples from each mine.

Results Toxicity Tests to Characterize the Extent of Mining Impacts to Streams

Clear Creek and its Tributaries Water Column Toxicity Tests - Samples were collected by Region VIII personnel and shipped overnight to Cincinnati to be tested within 72-hrs of collection.



Alamosa River Toxicity Characterization Study - Impacts from Summitville Mine
Samples for the Summitville Superfund Site were tested on-site over a two week period from 9-19-94 to 9-30-94. All samples were collected by personnel from the USEPA Region VIII Monitoring and Standards Section and ORD NERL-Cincinnati. All toxicity tests were started within 36 hours of sample collection. Tests were conducted in Mobile Bioassay Laboratories provided by USEPA Region VIII.



FINDINGS

We have demonstrated the utility of toxicity testing of water, discharges and sediments for characterizing the extent of contamination from mining discharges as well as using toxicity testing to assess the effectiveness various treatment technologies in removing metals and toxicity from mine drainage. Several of the Minewaste Technologies show the best short term and long term solutions to reducing impacts from mines.

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